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EARTHQUAKE HAZARDS AND THE URBAN ENVIRONMENT

by

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Introduction

The earthquake has been a common feature in the evolution of planet earth, and because of a rapidly growing population, millions of urban inhabitants presently live on or near major seismic zones.<sup>1</sup> Approximately 20,000,000 people alone live along the famous San Andreas fault of California. One must conclude, that based on the concept of uniformitarianism, major earthquakes will continue to occur, and that in terms of human life and property damage, the losses will no doubt be catastrophic when such an event centers on an urban environ. The only parameters that receive a disparity of agreement are when and where such an event(s) will take place.<sup>2</sup>

Many government agencies, private research groups, and university scientists have within the past decade directed an ever-increasing amount of research time towards earthquake mechanics, especially prediction and related topics including architectural design and the long term mental effects of children who have been

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<sup>1</sup> Earthquakes are most often associated with faulting or dislocation processes; a few minor ones are caused by volcanic eruptions or the subterranean movement of magma.

<sup>2</sup> More than 150,000 earthquakes occur throughout the world every year. On the average one earthquake (per year) reaches a sufficient magnitude to cause serious destruction in an urban area. (Duane D. Baumann and Robert W. Kates.) "Risk from Nature in the City," in Urbanization and Environment. Belmont, California: Duxbury Press, 1972, p. 188.

in earthquakes. For this reason, an Exchange Bibliography has been completed which treats the various aspects of earthquake hazards and the urban environment.

### Earthquake Hazards

When faulting occurs vibrations are activated, and three wave types are propagated by the earthquake: (1) P-waves, primary or push waves, (2) S-waves, secondary or shake waves, and (3) surface waves. P- and S-waves are characterized by rapid vibrations and small movement, but by contrast, surface waves have larger amplitudes, lower frequencies, and most of the direct earthquake damage is attributable to surface waves. In addition to earthquake wave damage, catastrophic damage occurs in the seismic or shatter zone where the actual faulting occurs and by tsunamis or seismic sea waves.

Shaking and vibrations often cause considerable urban damage because of landslides, land spreading, and the subsidence of unconsolidated sediments, including land fills. Vibrations are much more intense in loose material as opposed to bedrock and even the best designed buildings may fail structurally if there is ground failure. This concept is clearly depicted by filling a test tube with sand, noting the level, and then tapping the tube. The vibrations cause the sand to settle, and a new level is created.

California for example is noted for large expanses of both natural and man-made unconsolidated sediment areas. Unfortunately, most of these areas have been used for urban development.

Excluding fire, the greatest damage in the 1906 San Francisco earthquake centered on structures located on former tidal flats, which were representative of loosely consolidated sediments.<sup>3</sup> Structures simply collapsed when the ground failed and settled. The figures would no doubt be staggering concerning the populous in California who live on unstable sediments within fault zones, and how many of these are actually aware of the dangers involved.

Considerable earthquake damage in California and Peru has been caused by landslides. There are many shale and clay cliffs within the former's active seismic zones and when quakes occur there has been slippage along bedding planes of these rock units, and mass movement on a grand scale has occurred. Landslides are especially severe if these sedimentary rocks have been saturated with water. Such saturation lessens the frictional drag between the bedding planes.

Coastal cities located within the Pacific basin are vulnerable to tsunamis. Such seismic sea waves are most often generated when vertical displaced block movements occur on the ocean floor, but on the local level tsunamis can also be generated in harbors, estuaries, or lakes when landslides, activated by faulting, occur adjacent to or below the water bodies. Such waves can attain heights exceeding 50 feet, and tsunami damage can occur thousands of miles from the earthquake epicenter. For example, a tsunami created by the 1964 Alaskan earthquake reached Antarctica, and 11 people were killed in Crescent City, California. A 1946 earthquake in the Aleutian Trench generated a 57 foot tsunami;

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<sup>3</sup> The earthquake that struck Managua, Nicaragua, on December 24, 1972, was a catastrophic disaster because in large part most of the city's buildings were underlain by a loose, ashy base.

the damage in Japan and Hawaii exceeded \$10,000,000 and 173 lives were lost.<sup>4</sup>

### Future Prospects

It is inevitable that earthquakes will continue to strike urban environments throughout the world. In fact the number may actually grow as a result of an increasing number of urban centers encroaching upon high risk seismic zones. For example no lives were lost in the New Madrid earthquakes of 1811 and 1813 because the area was sparsely populated.<sup>5</sup> However, if the same area, now densely populated, was to be struck by earthquakes of the same magnitude today, the events would be quite different. The identical pattern is also occurring in California where certain southern desert areas are experiencing rapid urbanization. Unfortunately, the region is traversed by several active faults (e.g., San Gabriel, Garlock, Imperial, San Jacinto, Banning, and Elsinore).

We must also accept the notion that losses in terms of human life and property damage may be extremely large. This is attributable in large part to the following parameters: (1) many large population centers are located near or within active seismic zones, (2) earthquake oriented laws are most often not enforced, (3) earthquake oriented laws are non-existent in many countries, (4) there is an overall apathy of the populous concerning earthquake hazards, and (5) there exists cultural pressures to rebuild

<sup>4</sup> George R. Rumney. The Geosystem. Dubuque, Iowa: Wm. C. Brown Co., 1970, p. 83.

<sup>5</sup> The earthquakes were centered in southeastern Missouri, and complex geomorphic alterations, including the formation of Reelfoot Lake, occurred in northwestern Tennessee. Some geologists believe that because of the extent of geomorphic disruption, the earthquakes may have been the strongest ever to hit North America.

as soon as possible following an earthquake. Take for example the San Fernando, California, earthquake of February 9, 1971. Although it lasted for only one minute, 64 people were killed, and the urban damage was catastrophic. Table I summarizes a preliminary estimate of the damage.

A large portion of the discussion heretofore has centered on earthquake hazards in developed countries, but major earthquakes have also struck cities in underdeveloped countries, where building standards and land use codes are most often sub-standard or non-existent. This became especially apparent when Managua, Nicaragua, was virtually destroyed by a December 24, 1972, earthquake. In Managua, a city of 400,000, approximately 8,000 people were killed and more than 20,000 injured. Most of the casualties were found beneath rubble that once represented flimsy building materials. Up to 90% of the city was totally destroyed. In addition, utilities such as water, electricity, and telephone systems were rendered inoperative, and countless fires continued to burn for a week following the quake. The devastation was so catastrophic and complete that the Nicaraguan government initiated a geological investigation to ascertain whether the city should be reconstructed on its present site or whether an alternative location would be more desirable.

Most would agree that a basic problem common to the dilemma of urban earthquakes is the lack of responsible land use planning. We cannot of course abandon our cities and rebuild, but we can lower earthquake hazards to more acceptable limits. In response

TABLE I

## ESTIMATE OF DAMAGE, SAN FERNANDO EARTHQUAKE

| STRUCTURE         | NO. DAMAGED | AMOUNT \$   |
|-------------------|-------------|-------------|
| Schools           | 180         | 22,500,000  |
| Hospitals         | 4           | 50,000,000  |
| Residential       | 24,362      | 179,500,000 |
| Homes             | 21,761      |             |
| Apartments        | 102         |             |
| Mobile Homes      | 1,707       |             |
| Commercial Units  | 542         |             |
| Miscellaneous     | 250         |             |
| Highways          |             | 27,500,000  |
| Dams              | 5           | 36,500,000  |
| Public Units      |             | 145,000,000 |
| Utilities         |             | 42,000,000  |
| Personal Property |             | 50,000,000  |

Source: Reuben Kachadoorian. "An Estimate of the Damage," in The San Fernando, California, Earthquake of February 9, 1971. Geological Survey Professional Paper 733, Washington, D.C.: U.S. Government Printing Office, 1971, p. 5.

to planning, certain urban land uses should not be permitted in high risk areas. A prime example of an apathy towards seismic hazards can be found along a major fault in California. From Berkeley to Hayward some 36 public buildings are located on or within 1,000 feet of the fault trace; included in the 36 figure are 21 schools and three hospitals. Areas such as this should be zoned for land uses that are compatible with the geology.

A common assumption is that one should learn from his mistakes, but in terms of earthquake hazards and reconstruction, the phrase most often falls upon deaf ears. This was especially true in the United States for the San Francisco (1907) and Anchorage (1964) earthquakes. The following phrase will undoubtedly be repeated many times in the future.

It is very probable that the new city to rise on the ruins...will be to a large extent a duplicate of the former city in defects of construction.<sup>6</sup>

In addition to improved land use planning and the need not to rebuild immediately, many other avenues need to be explored and exploited. National governments should allocate funds so that research at an accelerated pace can center on pertinent items such as earthquake predicting, structural design improvements, and intensive geological mapping projects. The masses must also be educated to the potential hazards of earthquakes. However, based upon past experiences, little will probably be accomplished until a major American city is totally destroyed.

<sup>6</sup> E. Jack Schoop. "Development Pressures after the Earthquake," in Geologic Hazards and Public Problems. Edited by Robert A. Olson & Mildred M. Wallace, Washington, D.C.: U.S. Government Printing Office, 1969, p. 232.

Conclusions

It is hoped that this Exchange Bibliography will be useful to researchers, user agencies, and to those who simply want to become better informed. The authors would appreciate notification of any errata or suggestions for improving future compilations.

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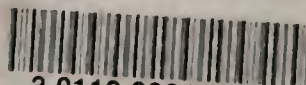
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